EDLIN, H. L. 1951. *British Plants and their uses.* London, Batsford Ltd.
EVANS, G. A., and N. V. Sherlock. 1949. Butler's Swamp, Claremont. *West. Aust. Nat.,* 2: 152-160.
GARDNER, C. A. 1952. *Flora of Western Australia,* vol. 1. part 1— Gramineae. Perth, Govt. Printer.
GRIGSON, G. 1974. *A dictionary of English plant names and some products of plants.* London, Allen Lane.
HOWES, F. N. 1974. *Dictionary of useful and everyday plants and their common names.* Cambridge, C.U.P.
HEYERDAHL, T. 1952. *American Indians in the Pacific.* Stockholm. Allen and Unwin.
HEYERDAHL, T. 1968. *Sea Routes to Polynesia.* London, George Allen and Unwin.
HEYERDAHL, T. 1971. *The Ra Expeditions.* Trans. Patricia Crampton. London; Allen and Unwin.
LAWRENCE, G. H. M. 1962. *Taxonomy of vascular plants.* New York: Macmillan.
McCOMB, J. A., and A. J. 1967. A preliminary account of the vegetation of Loch McNess, a swamp and fen formation in Western Australia. *J. R. Soc. W. Aust.,* 50: 105-112.
MOLDENKE, H. N., and A. L. MOLDENKE. 1952. Plants of the Bible. *Chronica Botanica,* vol. 28. New York, Roland Press.
New English Dictionary. 1914. ed. J. Murray. Oxford, O.U.P.
SAINTY, G. R., and R. F. Brayne. 1973. *Aquatic Plants—Identification Guide.* Water. Conserv. & Irrigation Commission. N.S.W. Aust.
Shorter Oxford English Dictionary. 1973. 3rd ed. Oxford, O.U.P.
WILLIS, J. H. 1962. *A handbook to plants in Victoria,* vol. 1. Melbourne, Melb. Univ. Press.
WILLIS, J. C. 1977. *A dictionary of the flowering plants and ferns.* rev. H. K. Airy Shaw. 7th ed. Cambridge, C.U.P.

NOTES ON THE TUART TREE *(EUCALYPTUS GOMPHOCEPHALA)* IN THE PERTH AREA.

By J. E. D. FOX* and S. J. CURRY**

INTRODUCTION

C. P. Brown of Wannanup wrote to *The West Australian* in 1978 (Letters, 24 August 1978):—

> As a ratepayer and resident of Mandurah, I am becoming increasingly concerned at the destruction of the surrounding bushlands by real estate developers. If commonsense prevailed, roads could be constructed through bush and the clearing of each block left to the discretion of the buyer. Even the lopping of the bigger gum trees would be preferable to their complete destruction. It seems to me that stupidity and greed are mainly responsible for the diminishing flora and fauna and subsequently, the quality of life.

He was, of course, referring to the tuart, the big gum of Mandurah. It is not only development *per se* which leads to the loss of trees in the urban landscape. Any road or other opening alters the environment and exposes trees to more sun, more wind and a greater edge effect than in the natural condition in which trees have developed. In this paper we give an account of the tuart tree and some of the environmental influences affecting it in the metropolitan area, with particular reference to the effects of insects and of fire on trees at three locations near Perth examined in May 1978.

DESCRIPTION OF TUART

The timber of tuart is pale yellow, very hard and dense with a strong interlocked grain (Gardner, 1952) and close textured. It is one of the heaviest and strongest of Australian timbers with moderate durability; its density is 990-1060 kg m^3 (Hall *et al.,* 1975). In the State's early history tuart was valued for its toughness. It was used for keelsons, stern posts,

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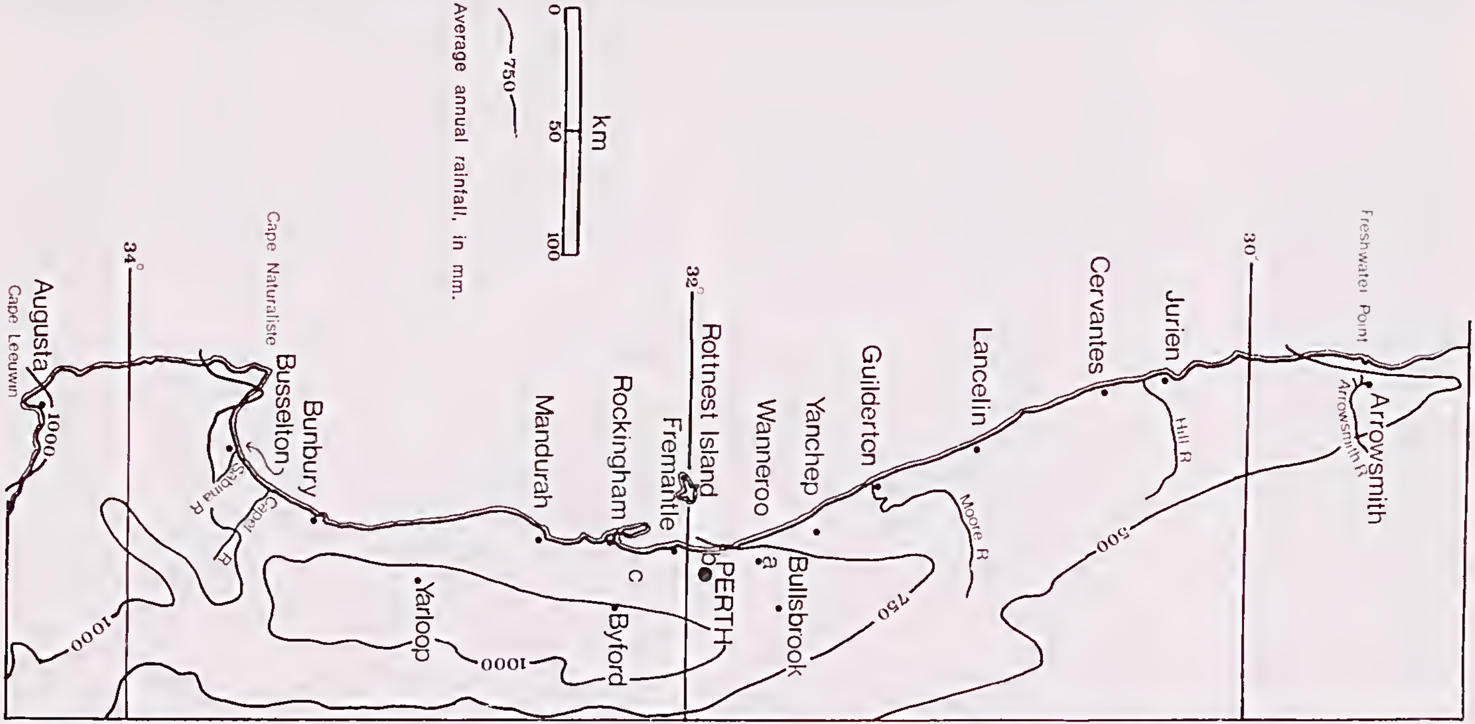

Fig. 1.—Location Map. This includes the extremes of distribution mentioned in the text; a, b, c are the localities sampled.

bridge supports, shafts and wheelwright's work and other applications where great strength, solidity and durability were required (Gardner, 1952). It was used until recently in the construction of railway wagons and earlier provided the pins to support telegraph insulators. Gardner also notes that the timber is reasonably termite resistant and is stronger than that of wandoo. It has the disinctive feature of complete lack of corrosive effect on metal objects such as bolts or dog spikes (Hall *et al.*, 1975).

The flowers yield a profuse good quality nectar and tuart honey is light coloured, of a pleasant flavour, and fine grained when candied (Gardner, 1952). Nectar yields are affected by damage to the flower buds caused by the tuart bud weevil (see below).

DISTRIBUTION OF TUART

Tuart occurs quite close to the ocean at a number of localities where shelter from the sea is afforded by high dunes. It is not found on the primary dune nor on the highly calcareous thin sands over limestone which occur as bands parallel to the coast. Its main occurrence is on the soil associations Karrakatta, Cottesloe and Yoongarillup. The first two are components of the Spearwood dune system in the vicinity of Perth. The Yoongarillup replaces Cottesloe south of Bunbury and may perhaps be the critical factor limiting tuart distribution to the south. Bettenay *et al.* (1960) show the Karrakatta as terminating at Sabina River (Fig. 1) whereas the Yoonagarillup Association continues westward almost to Carbunup Brook. In the metropolitan area tuart may be found up to 8-9 km inland from the ocean. North of Pinjar, and particularly in and around Yanchep, tuart extends into State forest. North of the Moore River it is generally confined to favourable topographic and edaphic combinations along the western boundary of State forest within about 6 km of the ocean (Havel, priv. comm.) It shows some tendency to follow rivers and is found by the Moore River at Cowalla 20 km inland. Elsewhere it is found at locations along the Canning River to 10 km inland, by the Swan River to 16 km inland and near Ravenswood on the Murray River 20 km from the ocean.

AREAS EXAMINED

Three localities were selected for examination (Fig. 1). The most northerly location was inland of Burns Beach, north-east of Lake Joondalup in the Wanneroo area about 25 km north of Perth (Fig. 2). Here tuart was found at 4.2 km from the ocean (site 1) and extended inland to 8.15 km from the ocean (site 2). A further 8 sites were selected between these extremes. Land clearing along Neaves Road did not permit confirmation of whether or not tuart occurred naturally to the east of Pinjar Road. At each site a plot containing at least one large tuart was considered and a total of 17 trees was examined.

The second location was the Bold Park area at City Beach. The area examined here closest to the ocean was < 1 km from the beach at the corner of Oceanic Drive and West Coast Highway. A further 4 sites were selected within Bold Park in the vicinity of Reabold Hill, and the site furthest inland (site 6) was south of Underwood Avenue opposite Birkdale Street, about 5.6 km from the beach. Tuart at this general latitude reappears further inland at Kings Park, about 9 km from the ocean. A total of 39 tuart was examined.

The most southerly location was the Kwinana area inland along Thomas Road. The western-most site (4) was just west of the railway and 1.8 km from the ocean. The eastern-most site (1) was located 2 km north of Thomas Road along Johnson Road at 8.5 km east of the ocean. A total of 20 tuart trees was examined.

Thus a total of 20 study sites at 3 latitudinal localities are discussed. The 76 tuart trees were measured for the physical dimensions of height, stem and crown diameter. Crown health was scored on a six-point scale from 0 (dead) to 5 (full crown). Soil samples were analysed from each site. The presence of insects was recorded, signs of fungal damage were noted, and the recent fire history of each area considered.

STATUS OF TUART IN STUDY AREAS

Tuart occurred in 'woodlands' or 'open forests' in the sense of Specht (1970). There was a tendency for taller trees to occur further south (Fig. 3). All areas examined were far from natural in their present condition. Felling, grazing and fires had all affected the stands to various degrees.

Soils

All sites were in the Spearwood dune system of Bettenay *et al.*, (1960) with 13 sites on their Cottesloe soil association and 7 on the Karrakatta.

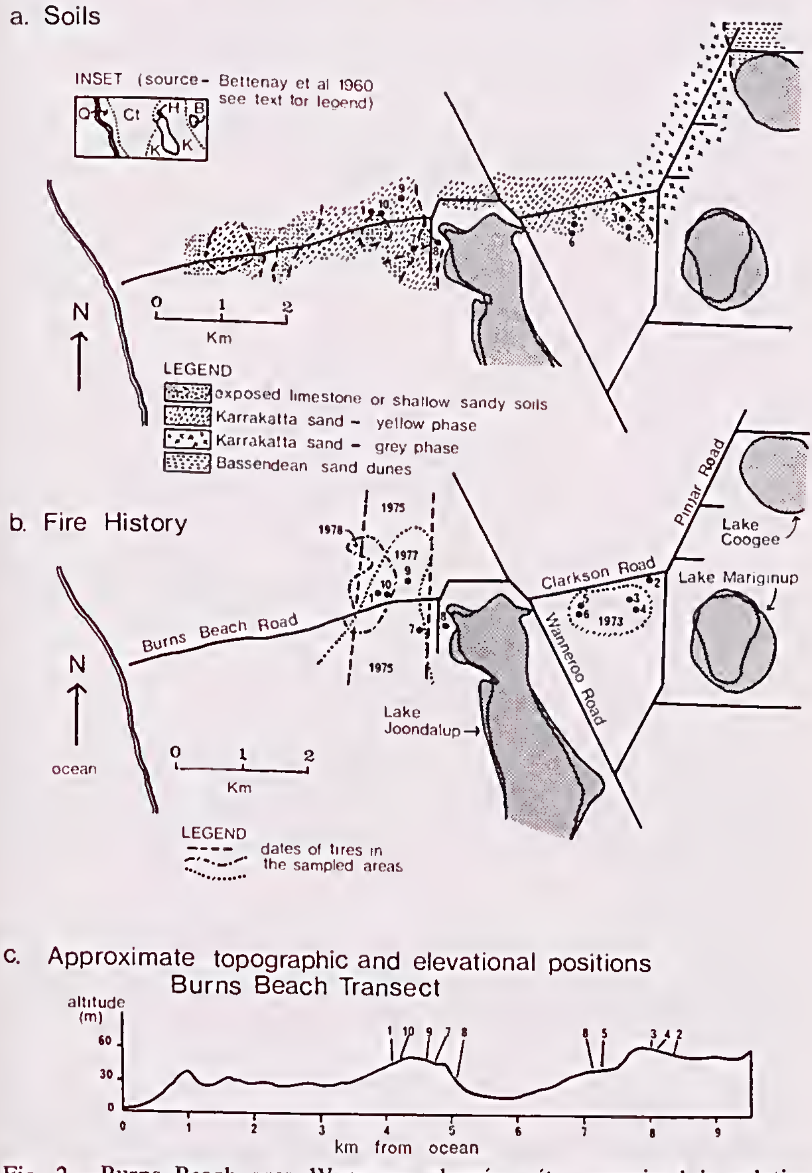

Fig. 2.—Burns Beach area Wanneroo showing sites examined in relation to soils, fire and topography.

Representative soil data are given in Table 1 for the Burns Beach sites and an extract from the map of Bettenay *et al.*, (1960) is given as an inset to Fig. 2 where: Q is Quindalup Association (coastal, white calcareous sand). H is Herdsman Association (organic swamp soils). Ct is Cottesloe Association (shallow sand over aeolianite). K is Karrakatta Association (deep sand over aeolianite). B is Bassendean Association (grey and yellow sand dunes).

The more detailed Shire of Wanneroo map, forming the main part of Fig. 2, suggests that all sampled sites fell in the Karrakatta Association and that all except site 2 fell on yellow/brown sands. No tuart was observed on the Bassendean Association though the 'grey phase' of the Karrakatta Association may well be an intermediate type of soil differing only in having limestone at depth. No tuart was observed on the soils mapped as 'exposed limestone over shallow sandy soils' which may be taken as being part of the Cottesloe Association.

Soil texture was sand or loamy sand at all sites. Soil colours in the Burns Beach area were mainly brownish (Table 1) while the Bold Park sites in general had greyer soils and Kwinana sites 2 and 3 were yellowish with 1 and 4 being brown to greyish brown.

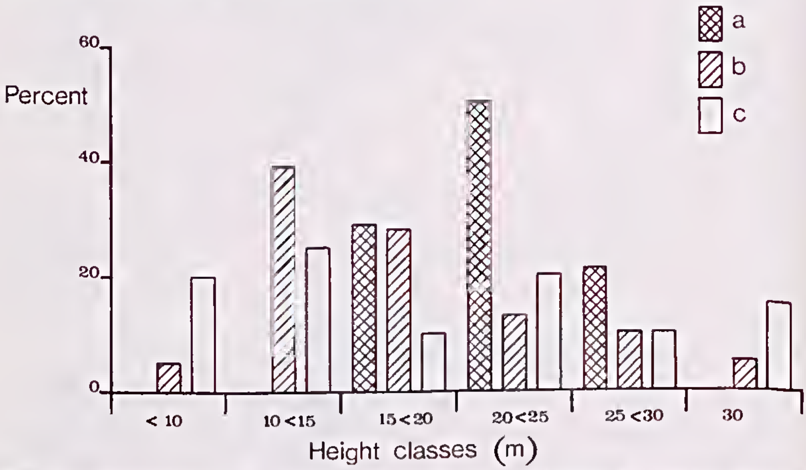

Fig. 3.—Percentages of assessed trees at each locality in height classes.

Carbonates were detected with dilute HC1 in samples from site 4 Burns Beach and site 4 Bold Park, both of which sites had a slightly higher pH than others at those locations. The mean pH ranged from 6.2 to 8.8. Surface pH and calcium content tended to be higher than for 30 cm samples. There was little trend in percentage soil moisture but percentage organic matter was generally higher for surface samples.

Communities

In this study particular emphasis was placed on presence of tuart regeneration, other eucalypt species and shrubs. Herbaceous plants, particularly annuals, were dealt with indifferently as most of the field work occurred at a time when these were neither conspicuous nor readily identifiable (April-May 1978). Several sites were severely infested with introduced annuals.

Table 2 provides an indication of frequency of eucalypts and the more abundant subsidiary trees and shrubs. Despite the inherent bias in selection of sites for tuart presence, both jarrah and marri were frequently encountered. Subsidiary tree species found with tuart were mainly the three banksias *Banksia attenuata*, *B. grandis* and *B. menziesii* and *Casuarina fraserana*.

TABLE 1.—SOIL CHARACTERISTICS BURNS BEACH STUDY AREA.

Site	Sample Depth (cm)	Soil Colour	Texture	Percentage Sieve Fractions			% organic matter	pH	Ca mg 100g−1	% moisture	Soil Association (Ct=Cottesloe K=Karrakatta)
				> 710μ	180-710μ	<180μ					
1	10	Brown/dark brown	10yr 4/3 loamy sand	24	71	5	2.2	7.1	21	4.1	Ct
	30	Dark brown	10yr 3/3 sand	26	70	4	1.7	7.3	19	4.0	
2	10	Light grey/grey	10yr 6/1 loamy sand	22	77	1	1.9	7.2	16	1.8	K
	30	Grey	10yr 5/1 sand	24	75	1	1.3	6.9	14	2.4	
3	10	Dark greyish brown	10yr 3/2 loamy sand	22	73	5	2.2	7.1	22	5.3	K
	30	Brown/dark brown	10yr 4/3 sand	19	76	5	1.2	7.0	11	4.1	
4	10	Yellowish brown	10yr 5/6 loamy sand	11	81	8	1.7	8.8	100*	4.5	K
	30	Yellowish brown	10yr 5/6 loamy sand	11	84	5	0.8	8.3	26*	3.9	
5	10	Brown	10yr 5/3 loamy sand	16	80	4	1.4	6.9	28	3.4	K
	30	Yellowish brown	10yr 5/4 loamy sand	16	81	3	1.1	6.8	22	3.0	
6	10	Dark yellowish brown	10yr 4/4 loamy sand	16	79	5	1.2	6.2	20	4.2	K
	30	Dark greyish brown	10yr 3/2 sand	19	76	5	2.2	6.4	32	5.9	
7	10	Dark brown	10yr 3/3 loamy sand	15	79	6	3.9	7.7	61	3.8	Ct
	30	Dark yellowish brown	10yr 4/4 sand	14	82	4	1.6	6.9	31	2.5	
8	10	Dark greyish brown	10yr 3/2 sandy loam	21	73	6	2.7	6.7	25	5.3	Ct
	30	Dark brown	10yr 2/2 sandy loam	23	72	5	2.3	6.8	30	4.1	
9	10	Brown	10yr 5/3 loamy sand	18	75	6	2.5	7.1	35*	1.5	Ct
	30	Dark yellowish brown	10yr 4/4 sand	18	76	6	1.5	7.1	29	2.4	
10	10	Dark greyish brown	10yr 3/2 sand	36	60	4	3.8	7.0	35	7.1	Ct
	30	Dark yellowish brown	10yr 4/4 sand	33	63	4	1.0	6.7	18	7.0	

*Carbonates detectable on addition of HC1 to soil.

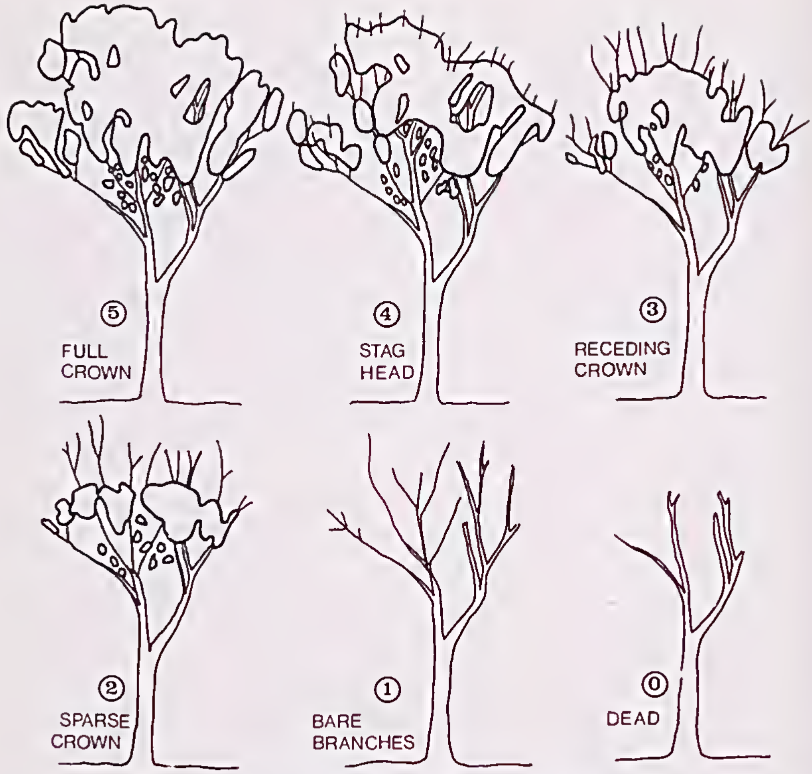

Fig 4.—Scoring system for crown health status.

TABLE 2.—ASSOCIATED SPECIES

Species	Number of sites Present	Frequent*	Abundant*	Total sites
Large trees				
Eucalyptus gomphocephala	6	6	8	20
E. calophylla	1	2	1	4
E. marginata	2	4	4	10
Subsidiary trees				
Banksia attenuata	10	2	—	12
B. grandis	3	—	—	3
B. menziesii	8	1	—	9
Casuarina fraserana	6	—	—	6
Shrubs				
Acacia cochlearis	1	—	—	1
A. pulchella	8	2	—	10
A. saligna	4	1	—	5
Dryandra sessilis	1	1	1	3
Jacksonia furcellata	5	3	—	8
J. sternbergiana	4	1	—	5
Macrozamia riedlei	13	3	1	17
Melaleuca heugelii	3	—	—	3
Xanthorrhoea preissii	4	4	4	12

*Frequent: 10-49 individuals, *Abundant > 50, per 0.03 ha sample.

Crown Health

All tuart trees were scored for crown health as in Fig. 4. This system allows progressive stages in crown deterioration to be recorded and individual large trees to be compared. We are confident that loss of foliage can be largely attributed to the effects of fire and insect damage, to be discussed below.

The categories used are more or less coincident with the scale used by Beard (1967) viz:—

Present Study	Beard (1967)
0 Dead	Dead
1 Bare branches	Died back to base
2 Sparse crown	Died back to 0-1/3 of height
3 Receding crown	Died back to 1/3-2/3 of height
4 Staghead	Stagheaded
5 Full crown	Full foliage

At only 8 of the 20 sites examined was crown health of the largest tree present of category 4 or 5 (Table 3). Two large tuart at Kwinana site 3 scored 1 only, with one other scoring 4. In general trees with larger crowns scored higher on crown health. Evidence of possible fungal pathogens at work was noted at sites 4, 7 and 9 of the Burns Beach set. Here patches of dead understorey trees and shrubs suggested presence of the dieback fungus *Phytophthora cinnamomi* or the honey fungus *Armillaria mellea*.

INSECTS ON TUART

A large range of insects attack tuart. In the following account these are put in three damage groups: firstly damage to flowers, then to wood, and finally defoliating species.

(A) Damage to flowers

Tuart bud weevil *Haplonyx tibialis** Curculionidae. An account of this interesting creature was given by Newman and Clark (1924) and Jenkins (1972).

TABLE 3.—CROWN HEALTH STATUS OF LARGEST TREE AT EACH SITE.

Locality	Site	Largest tree: Crown Health (1-5)	Largest tree: Height (m)	Largest tree: Crown Diameter (m)	Number of tuart trees examined per site
Burns Beach					
	1	3	20	9	1
	2	4	22	18	1
	3	1	29	6	2
	4	3	25	8	4
	5	1	25	3	1
	6	3	23	10	1
	7	4	28	12	3
	8	3	18	11	2
	9	3	24	9	1
	10	2	16	7	1
Bold Park					
	1	4	29	20	7
	2	4	30	12	10
	3	3	17	8	7
	4	3	22	8	6
	5	5	31	22	5
	6	3	35	8	4
Kwinana					
	1	4	34	22	3
	2	3	27	11	2
	3	4	21	11	3
	4	5	21	22	12

*Not *tibialis* as in Seddon, 1972, page 118.

Its effects have been observed from at least 1880. Between November and April numbers of terminal bud bearing twigs may be found around the base of the trees. The adult weevils may be found at all seasons of the year, they are about 6 mm long and 4.5 mm broad with the females larger than the males. The colour is brownish with two lighter bars across the front of the wing covers. The snout is half as long as the body and the front legs are twice as long and stout as the second and third pairs.

The female drills a hole in the capsule of the flower bud and deposits a single egg. The hole is then plugged with tissue. The weevil may then repeat the process with other buds on the same twig. It then returns along the twig and cuts it off or ring barks it. The twig may fall during the cutting or it may persist on the tree for some time. The weevil may also cut off bud bearing twigs without laying any eggs in the buds or cut off twigs some of whose buds have not been drilled.

The white, elongate-oval egg is less than 1 mm in length. The egg hatches in 8-12 days in the fallen flower bud. The larva feeds in the top part of the bud for some four months. As it grows it assumes the typical weevil appearance and remains curled up in the bud. Prior to pupation the larva bores into the basal part of the bud. The pupa is naked, white and very active when disturbed. Pupation lasts about a month then the adult cuts its way out of the base of the flower bud.

Newman and Clark (1924) observed a parasite of the tuart bud weevil. This was a species of Braconid wasp of the genus *Iphiaulax* which oviposits an egg into the body of the developing weevil larva within the flower bud. A small maggot hatches and feeds on the host destroying it prior to the pupal stage.

The tuart bud weevil is found throughout the range of the species though it seems to cause more damage at the present time in the Perth area and at Yanchep than it does further south.

It is not known whether infestation is at higher levels in years of dense blossom though clearly the possibility of collecting seed should be higher following heavy flowering. No observations are available on the relative numbers of adults in relation to the wetness of winters. Tuart bud weevil damage was noted on trees at sites 1, 2, 6, 7, 9, 10 at the Burns Beach locality and for sites 1 and 10 was of particular importance as these two had only recently been burnt (April) suggesting that debudding is not inhibited by summer fires.

Other weevils, of the genus *Catasarcus*, which are mainly confined to Western Australia, feed as adults on leaf edges. These are relatively large, spiny, wingless and black/green in colour. The larvae live in the soil on roots. Though of nuisance value only they are found frequently on tuart.

A number of Twenty-eight Parrots *(Barnardius zonarius)* as well as a few Red Wattle-birds *(Anthochaera carunculata)* were observed in tuart trees near Lake Preston causeway in April 1977. These appeared to be feeding on insects on twigs and in bark. A large amount of fallen blossom (on twigs) was observed under the trees after the feeding event.

(B) Damage to Wood

Tuart borer *Phorocantha impavida* Cerambycidae.

Bark discoloration on branchlets may indicate the presence of tuart borers. Adults of this longhorn beetle emerge from September to December with a flush in the Perth area in October in alternate years. They survive for only a week to mate and oviposit and are active night fliers. Eggs are laid in cracks in the bark and the larvae hatch within a few weeks. These bore under the bark for 12 to 18 months before pupating in the sapwood. This stage is indicated by the presence of one plugged hole and an adjacent un-plugged hole on the surface of the sapwood.

The main effect of this insect is ring-barking leading to death. Trees from 3 - 4 years of age can be attacked leading to epicormic growth lower down the stem. Younger trees die from this form of attack faster than bigger, older ones (Powell, priv. comm.) Large trees are attacked in the smaller branches and many cases of stag-headed tuart are attributable to the tuart borer. The borer seems able to attack apparently healthy trees. There is every suggestion that environmental changes may have increased the incidence of this form of damage.

Many tuarts in the Perth metropolitan area bear conspicuous dark brown stains on many of the smaller branches as a result of borer attack. It is not, however, an entirely recent phenomenon as very high losses to planted tuart were attributed to the borer in 1939 (Wycherley, priv. comm.)

A related species *Phoracantha semipunctata* occurs in eucalypts in all states of Australia and has also been introduced to Israel (Britton, 1970). It may attack dead trees of tuart and has a life cycle of one year with emergence during summer.

Two other types of Cerambycids occur as dead wood borers in tuart. These are *Coptocercus* and *Bethelium* whose larvae bore under the bark so that it comes away from the stem.

Stem girdler *Cryptophasa unipunctata* Lepidoptera.

The stem girdler attacks a number of species. The adult moth lays eggs on the bark. On hatching the larvae feed on bark and bore into the centre of the stem then they tunnel down the centre for 5 cm. The openings to the tunnel and bark galleries are covered in a web meshed with masticated bark fragments. Smaller branches are ring barked and considerable damage to stems up to 15 cm diameter may occur. The larvae shelter in the tunnel during the day, emerging to feed at night. This insect may cause stag-headedness following some pre-disposing weakening of the tree, e.g. fire or drought.

Moth larvae, *Culama* sp. (Cossidae) bore under the bark usually following the tuart borer. The pink coloured caterpillars produce brown frass particles which cause the bark to become detached from the sapwood. In conjunction with *P. impavida* these larvae, which bore for only a few months with an annual life cycle, contribute to ringbarking and death.

Pin-hole borer *Atractocerus kreuslerae* Lymexylidae.

These beetles emerge between December and March, living as adults for a few days only. Eggs are laid in wounds or fire scars, dry areas usually some years old and already deteriorating. The larvae bore into the heart wood mainly horizontally, ejecting frass strings through the entrance holes. They feed on a fungus which grows on the inside of the galleries and remain as larvae in the wood for several years. When full-grown they return to the surface of the wood to pupate behind plugged holes. Damage is confined to the horizontal zone of wood near the original wound.

(C) **Damage to leaves**

Leaf damage to young trees is caused by a range of insects, including the weevils referred to above. Caterpillars of the pasture looper *(Ciampa* sp., a moth in Geometridae) occasionally defoliate young trees in or near old pastures. The tuart miner *(Nepticula* sp., a moth in Nepticulidae) attacks the lower leaves of young trees in the Ludlow area during July-August. Larvae mine the leaf tissue causing them to brown off and die. The damaged tissue falls to the ground where the larvae pupate in the soil to emerge as minute moths some ten months later. Leaf miner damage was observed at sites 4, 6, 7, 9 in the Burns Beach locality, with damage particularly severe at site 6. Christmas beetles (Scarabaeidae) defoliate gums in Eastern Australia and have been implicated in dieback (Anon., 1979). We have no record of this in connection with tuart. Particularly severe damage was caused to young tuart plants at the WAIT field trial area in Autumn 1979 (May/June) by the leaf blister sawfly *Phylacteophaga froggatti* (Pergidae). The plants affected were in pots and 50-100 cm tall. A number of planted *Eucalyptus* species on the WAIT campus suffered severe leaf blister and necrosis on foliage lower than 7-8 m only.

Spitfires are the sawfly larvae which congregate for protection *(Perga* spp., of the Pergidae). These may do considerable damage to young trees and regrowth between late winter and early summer, though affected trees are usually scattered. Pupation occurs in the soil beneath the affected tree. Parasitic wasps are believed to be important in controlling numbers and hence preventing large scale damage.

Defoliating beetles (*Paropsis* spp. of the Chrysomelidae) are serious pests of eucalypts in New South Wales and New Zealand. In W.A. they do not cause extensive damage probably due to parasitic control as with *Perga* spp. Both adults and larvae feed on leaves: the beetles scallop leaf edges while the larvae chew through the leaf surface and tissues.

Sucking bugs of the order Hemiptera are found on tuart foliage and suck sap causing at least localised death. These include leaf hoppers (Eurymeliadae, Membracidae), shield bugs (Pentatomidae) and lerps (white, waxy larvae of Psyllidae). Bugs seem to be quite numerous at Ludlow where their attacks could contribute to dieback.

Natural regeneration south of Mandurah frequently suffers from insect larval attack and some damage has been noted at all times of the year. Insects have proved troublesome in Forests Department trials by deforming seedlings and grasshoppers may also do damage (Keene and Cracknell, 1972).

In the present study generalised insect damage to foliage (apart from leaf miner attack referred to above) was noted at most sites. It was more noticeable on trees at Burns Beach sites 1, 2, 5, 6, 7, 8 and 9 and on young tuart at site 1 of the Kwinana locality. Epicormic shoots at Bold Park sites were most affected.

THE EFFECTS OF FIRE

Tuart trees are affected by fire to varying extents, with leaf scorch the minimum level of damage to the crown. Leaves will be shed and new ones produced. When the branchlets are damaged, however, new growth comes from older wood with thicker bark. Repeated damage to the crown may lead to stagheadedness, and though most stagheaded trees in the Metropolitan area owe their appearance to borer attack, it is likely that fires also play a part.

Fire frequency also affects survival of regeneration. Freedom from competition and fire are necessary until the trees are established. Sterilisation of the soil by heat ensures there is no herbaceous material close to the tuart growing on ashbeds and the fire removes fuel sources. At Ludlow young tuarts on ashbeds will get away under these conditions after 1 or 2 years (McKinnell, priv. comm.)

The incidence of fire has been reasonably elucidated for the Burns Beach Road sites with assistance from Wanneroo Shire and the local Forests Department staff (Fig. 3). Tuart at sites 3, 4, 5 and 6 suffered fire damage in 1973 from which they had recovered poorly by the time of assessment. Fires following cyclone Alby (April 4, 1978) destroyed some 50 per cent of crowns at sites 1 and 10, which had also suffered fire the previous summer. Only at sites 2 and 7 in the Burns Beach area were crowns scored as high as health category 4. No tuart regeneration was observed at any of the 10 sites. It is of some interest that sites 7 and 9 with highest species numbers for the Burns Beach set had considerable numbers of *Dryandra sessilis* (46 and 58 individuals within a 10 m radius of the tallest tuarts). This species is one of several which may be of some utility in dating fires as well as being an indicator of community change and succession (Marchant, 1975). Clearly the 1977 fire had not been very intense at these sites but may still have removed any tuart seedlings that may have been present.

Early photographs of the Bold Park area suggest that prior to development there was a dense tuart/jarrah stand with full crowned tuart trees. A photograph taken about 1918 shows the plank road or 'switchback' under construction, about 200 m from site 2. Fire damage to the trees here in 1978 was extensive, with the most recent fire in the preceding summer leaving at least two large trees with new foliage at the base only and having destroyed epicormic growth from several others. It is possible that, here at least, jarrah is persisting rather better than tuart.

Site 1 at Bold Park, in a highly urbanised setting, showed no signs of recent fire damage. However it, as with much of the main park area, was overrun with exotic weeds and contained no tuart regeneration. Most trees at the other sites of this locality showed extensive fire damage. Wildfires lit by vandals are a major problem in the Bold Park/Reabold Hill area.

The Kwinana sites showed an interesting pattern of frequency of fire related to land development. Site 4 in an industrial area had been regularly burnt annually; 2 and 3 in or near residential areas were burnt frequently; while site 1, somewhat remote from development had been burnt less frequently. The presence of old charred logs at the latter site, coincident with occurrence of tuart regeneration (the only example recorded from all 20 sites), suggests that sufficient litter had accumulated to create ashbed conditions conducive to regeneration about 2 years earlier.

CONCLUSIONS

Top death of tuart in the metropolitan area is usually a result of insect damage and may be compounded by other environmental influences. In areas subjected to burning loss of crown foliage may predispose trees to insect attack or fungal pathogens. However we consider that fire is the main influence on degradation of tuart woodlands as a whole.

Progressive stages of degradation can be postulated. Firstly large trees will eventually burn away. This may occur over a protracted time period. It may well be the natural way in which old senescent trees would disappear in the absence of modern civilisation on the coastal plain. Secondly the normal species composition of the tuart communities undergo alterations which further inhibit the chances of new tuart seedling establishment. Both types are operating simultaneously. As fires have increased in frequency the following detrimental consequences have occurred:

(a) young seedlings burnt before they are tall enough to resist fires;
(b) introduced annuals favoured which provide competition (for moisture in particular) for tuart seedlings, and which increase the risk of annual burning by producing more inflammable material to further accentuate (a);
(c) insufficient fuel remains to provide adequate ashbeds for new seed to germinate into; and
(d) senescence of trees of seed-bearing size is hastened as crown regrowth may be burnt back. Coupled with bud weevil attack (on fewer available food sources?) seed production is reduced.

Clearly if all foliage is lost in a fire then with good leaf recovery from epicormic growth new seed will not be produced until several years after the fire (Gill, 1975). Fires which occur when there is no seed in the crowns or when the seedlings are small are clearly of no benefit to regeneration.

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REFERENCES

ANON. 1979. Requiem for the rural gum tree. *Ecos*, 19, 10-15.

BEARD, J. S. 1967. Natural woodland in Kings Park. *W.A. Nat.*, 10 (4) 77-84.

BETTENAY, E., W. M. McARTHUR and F. J. HINGSTON. 1960. The soil associations of part of the Swan coastal plain, Western Australia. *C.S.I.R.O. Soils and Land Use Series* No. 35.

BRITTON, E. B. 1970. Coleoptera. Chapter 30 in *The Insects of Australia*. C.S.I.R.O., Melbourne University Press.

GARDNER, C. A. 1952. Trees of Western Australia. Tuart and Illyarrie. *Bulletin 1096, W.A. Department of Agriculture.*

HALL, N., R. D. JOHNSTON and G. M. CHIPPENDALE. 1975. *Forest Trees of Australia.* Aust. Govt. Publ. Serv., Canberra.

JENKINS, C. F. H. 1972. Insect Pests of Forests (3). The tuart bud weevil and the gregarious gall weevil. *Bulletin No. 3178, W.A. Department of Agriculture.*

KEENE, D. J. and E. M. CRACKNELL. 1972. Regeneration of tuart forest. *Forest Notes,* 10 (1) 14-17.

MARCHANT, N. 1975. Lakeland plant ecology, pp. 32-36. Seminar: The Peel-Preston Lakelands. University of Western Australia, Perth.

NEWMAN, L. J. and J. CLARK, 1924. The tuart bud weevil *(Haplonyx tibialis). Leaflet No. 145, W.A. Department of Agriculture.*

SEDDON, G. 1972. *Sense of Place.* University of W.A. Press, Perth.

SPECHT, R. L. 1970. Vegetation. In *The Australian Environment.* C.S.I.R.O.: Melbourne Univ. Press.

POLLEN LOADS ON HONEYEATERS IN A *GREVILLEA ROGERSONIANA* THICKET SOUTH OF SHARK BAY

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ABSTRACT

Three Singing Honeyeaters *(Meliphaga virescens)* and one Spiny-cheeked Honeyeater *(Acanthagenys rufogularis)* were mist-netted in a *Grevillea rogersoniana* thicket on Nature Reserve 36127 25 km SW of Cooloomla homestead on September 17, 1979. Pollen loads on both species of honeyeater consisted of large quantities of *Diplolaena microcephala* grains together with smaller amounts of *Grevillea rogersoniana* and *Banksia ashbyi* grains. The honeyeaters appeared to concentrate on *G. rogersoniana* and, to a lesser extent *B. ashbyi,* in their foraging for nectar. No feeding on *D. microcephala* was seen during 60 minutes observation in the early morning peak of feeding activity. The discrepancy between observed honeyeater foraging preferences and the relative proportions of pollen of the three plant species in pollen loads illustrates one of the divergent ways in which plants may compete for service by common pollinators.

INTRODUCTION

Prominent among the many aspects of honeyeater-plant relationships deserving study in Western Australia are questions concerning the pollen loads picked up by honeyeaters when foraging at flowers. A few recent investigations have shown that pollen of several plant species (usually 3-5, sometimes up to 12) may be carried by honeyeaters in a given habitat, but that pollen of one or two species normally predominates in the load (Paton and Ford, 1977; Burbidge *et al.,* 1979; Hopper, 1980). Moreover, there is limited evidence available indicating that the proportions of pollen of each species carried by honeyeaters are not necessarily equivalent to the frequency at which the birds visit the flowers of each plant (Hopper, 1980). This suggests that plants differ in their ability to transfer pollen to honeyeaters. The nature of such differences and the selective regimes under which they arise warrant careful study.

The present publication reports on a small investigation of pollen loads on honeyeaters made in September 1979 while I was assisting in a biological survey of a 50,000 ha Nature Reserve (Department of Lands and Survey No. 36127) located between Shark Bay and the Lower Murchison River. This Nature Reserve contains populations of a number of plants endemic in the region, including *Grevillea rogersoniana* (Proteaceae), a shrub up to 3 m tall that has pink flowers arranged in erect inflorescences that exude copious amounts of nectar.

Initial observations at a campsite in a *G. rogersoniana* thicket on the reserve 25 km SW of Cooloomia homestead (27°08'S, 114°08'E) indicated that large numbers of Singing Honeyeaters *(Meliphaga virescens)* and a few Spiny-checked Honeyeaters *(Acanthagenys rufogularis)* were feeding on the nectar of the *Grevillea.* The thicket contained an understorey of several shrubs including *Diplolaena microcephala* (Rutaceae) in full flower, and nearby was a grove of *Banksia ashbyi* (Proteaceae) trees 5-10 m tall with